D. C. MOTORS

PART V: THE SERIES MOTOR

OBJECTIVES

student will:

. Draw the necessary connections between given symbo that will complete a schematic diagram of a series motor circuit.

. Select, from a list of statements, the reason why series motors are widely used.

. Complete a statement about the factor that limits armature current in a series motor which is supplied with a constant applied voltage.

. Select, from a list of statements, the reason why a series motor must always be connected to a load.

. Select, from a list of statements, the relationshi between torque and armature current in a series motor, and the effect on torque when armature current is doubled.

. Complete a chart showing the effects caused by a change of load on a series motor.

. Complete a statement that identifies the series motor generally used in D. C. actuators.

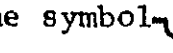
. Draw the necessary connections between given symbo that will complete a schematic diagram of a split-field series motor.

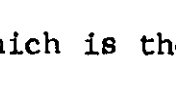
. Draw the connections necessary to complete a diagr of a lab machine that may be used for series motor experiments.

RECOMMENDED READING TIME 45 MINUTES

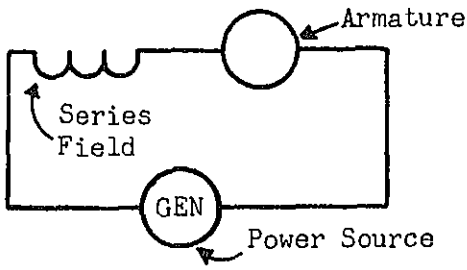
1. The field coils, consisting of a few turns of heavy wire, are connected in series with a rotating armature through a set of carbon brushes.

The field coils of a series motor are made of a _____ turns of heavy wire connected in series with the _____ through a set of carbon _____.

2. The series field is represented on a schematic diagram by the symbol  , which is connected in series with the armature, commutator, and brushes, represented by the symbol  . The power source that will be used throughout this program is a generator, represented by the symbol  .

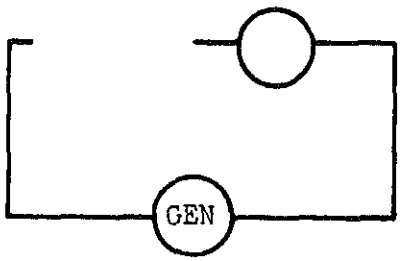
The symbol for the series field is _____, which is connected series with  , which is the for the _____, including commutator and brushes.

3. The schematic diagram below shows the electrical connections of a series motor.

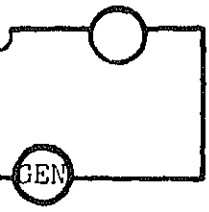


If power is applied to a motor, wired as shown above, it will operate as a _____ _____.

4. Complete the schematic diagram of a series motor shown below by drawing the missing symbol.

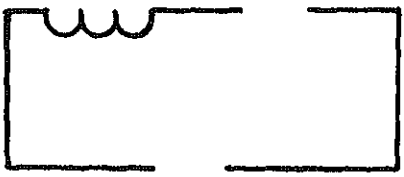


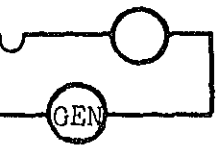
The symbol required above is the symbol for the _____ _____.



es field

5. Complete the schematic diagram be by drawing the symbols for the po source and the armature.

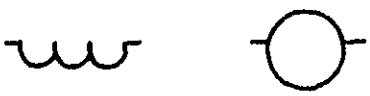


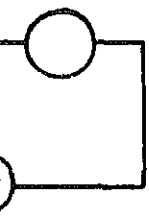


6. The series motor field and armatu windings must carry the full load current because the field and arm windings and the load are all con in _____.

es

7. Draw the necessary connections be the symbols below to complete a schematic diagram of a series mot circuit.





8. The series motor is widely used because it has HIGH STARTING TORQUE and rapid acceleration.
The motor widely used because of its high starting torque and _____ acceleration is the _____ motor.

9. An installation requiring a motor with high starting torque would use _____ series motor.
The series motor is used in installations that require high _____ _____.

g torque

10. Select, from the list of statements below, the reason that the series mot is widely used. Circle the letter in front of the answer of your choice.
   a. Series motors have good speed control and do not overheat.
   b. Series motors have high starting cemf and constant speed.
   c. Series motors have high starting torque and rapid acceleration.

ct

11. The heavy wire used in the construction of both the field and armature windings

motor has very little resistance. Since there

few turns of this heavy wire in the field and

ndings, the internal resistance of the series

ry low. When voltage is applied to a series

low internal resistance will allow high current

h the field and armature windings. Before the

gins to turn, the only thing that will oppose

w is the low resistance of the field and armature

hus, current flow will be maximum at start.

ture begins to turn, a cemf is induced into the

ndings which opposes the applied voltage and,

opposes the current flow from the power source.

duced into the armature windings limits the

w in a series motor.

motor has very _____ internal resistance.

he current flow in a series motor will be

imum because there is no induced cemf to

e)

the applied voltage.

)

w through a series motor that

tage is limited by the amount

o the armature windings.

m,oppose

12. In a series motor, with a constant applied voltage, the cemf induced into the rotating armature will oppo the E_{app} and the current through the field and armature windings will decrease. When the current through th windings of a series motor decreases the flux field produced by this current will decrease.

The cemf, induced into the rotating armature windings, limits the amount _____ through the field and armature windings.

t

The decrease in current flow through the field and armature windings, caused by the induced cemf, will decrease the _____ field.

13. In a series motor with a constant applied voltage the current flow through the field and armature windings is limited by the amount of _____.

14. As the armature begins to turn, the cemf induced into it causes the I_a to decrease, thus decreasing the torque.

Torque developed by a series motor decreases when the armature begins turn because cemf induced causes th armature current to _____.

se

15. A decrease in the current flow thro the armature and field windings cau field strength (β) to weaken and results in speed increasing. As th armature speed continues to increas cemf increases, and, as a result, th field strength weakens even more.

The weakening field strength, as sp increases, gives the series motor t feature of rapid acceleration to th point where it is producing only th torque required by the load.

A decrease in armature current cau field strength to increase/decrease (circle one)

se

Continue on next page.

A decrease in field strength results in a speed increase/decrease (circle one). This, in turn, causes cemf to increase and limit the _____ current to the value needed to develop the torq required by the load.

se
re

A series motor accelerates rapidly to the point where it is producing t _____ required by the load.

16. The series motor produces or develop the torque required by the load to which it is connected. The torque developed by a series motor is propo tional to armature current squared, $(I_a)^2$. At the moment of start, torq is maximum because armature current at its maximum value.

At start, maximum armature current in a series motor causes torque to be _____, because torque developed by a series motor is pro- portional to the _____ _____ squared.

17. If a series motor is started without a load attached, it will accelerate rapidly. With no load attached, the only torque required is that needed to turn the armature. The speed at which cemf would be of sufficient value to control I_a is in excess of design speed. The rapid acceleration of a series motor with no load on it will continue until the bearings burn out, or the armature windings are thrown out of their slots, thus destroying the motor. For this reason A SERIES MOTOR MUST NEVER BE STARTED WITHOUT A LOAD ATTACHED.

The torque produced by a series motor is proportional to _____ current squared.

If a series motor is started without a load attached, it will _____ rapidly to the point where it will _____ itself.

A series motor may sometimes be/must never be started with no load attached.

be	18. Select, from the list of statements below, the reason that a series motor must always be connected to a load. Circle the letter in front of the answer of your choice. a. The series motor must always be connected to a load so that it will not build up excessive counterelectromotive force. b. The series motor must always be connected to a load so that it will not build up excessive speed and destroy itself. c. The series motor must always be connected to a load so that it will not build up an excessive amount of armature current.
ect.	19. The torque developed in a series motor is proportional to the square of the armature current. In a series motor, the torque developed is proportional to the _____ of the armature current.

20. A series motor, carrying 2 amperes of armature current, will develop a definite amount of torque to carry a load. If the load is increased to where it takes four times the original amount of torque to carry the load, the armature current would increase to only 4 amperes. The fact that torque in a series motor is proportional to I_a^2 enables a relatively small change in armature current to correct for large changes in load. Doubling the armature current in a series motor will result in the motor developing four times as much torque.

Large changes in the load on a series motor will cause only
small change in

If the I_a of a series motor is doubled, the torque developed will be
_____ times the original value.

ture	21. The torque developed by a series mo is _____ to the square of armature current.
ortional	22. The torque developed by a series mo will increase to four times the ori inal value if the armature current _____.
ted	23. Select, from the list of statements below, the relationship between tor

armature current in a series motor and the effect on s torque when the I_a is doubled. Circle the letter i nt of the answer of your choice.

Torque in a series motor is proportional to the squa of the armature current; thus, doubling the I_a would cause an increase of four times the amount of torque being developed.

Torque in a series motor is proportional to the squa of the applied voltage; thus, doubling the I_a would h no effect on the amount of torque being developed.

Torque in a series motor is proportional to the arma current divided by the applied voltage; thus, doublin would double the amount of torque being developed.

ase

26. A decrease in the speed of a series motor will cause less cemf to be induced. When the cemf decreases and the applied voltage (E_{app}) is consta the effective voltage (E_{eff}) will in crease because $E_{eff} = E_{app}$ - cemf.

With constant E_{app}, a decrease in th speed of a series motor will cause t cemf induced to _____ and t E_{eff} to _____.

ase

ase

27. When the effective voltage increases the armature current will increase. Since the same current flows through the series field coil, the strength of the field (β) must also increase

An increase in E_{eff} will cause I_a t _____, which, in turn, will cause the strength of the series fi (β) to _____.

28. Load, torque (T), effective voltage (E_{eff}), armature current (I_a), and field strength in a series motor are all directly proportional. If the load on a series motor increases, T, E_{eff}, I_a, and β will all increase.

A decrease of the load on a series motor being supplied with a constant E_{app} will cause T, E_{eff}, I_a, and β to _____ because they are directly proportional.

29. A chart may be used to indicate the changes that occur within the series
the load is increased or decreased. Notice, in
below, that the proportional items vary in the same
The arrows up (⬆) indicate an increase and the
n (⬇), decrease.

	LOAD	SPEED	cemf	E_{eff}	I_a	β	T
nt	INCREASE	⬇	⬇	⬆	⬆	⬆	⬆
nt	DECREASE	⬆	⬆	⬇	⬇	⬇	⬇

NO RESPONSE REQUIRED

crease in the cemf induced. Complete the chart below to show the effect on torque, speed, and I_a when the load is decreased. Draw an arrow in the appropriate boxes, up (↑) to indicate increase and down (↓) to indicate decrease.

app	LOAD	SPEED	cemf	E_{eff}	I_a	β	T
onstant	DECREASE		↑	↓		↓	

Your completed chart in frame 30 should look like the chart shown below. If your chart does not agree, mak any corrections necessary before continuing with this frame.

E_{app}	LOAD	SPEED	cemf	E_{eff}	I_a	β	T
ONSTANT	DECREASE	↑	↑	↓	↓	↓	↓

ontinue this frame on the next page.

(Contd.) As load decreases, less torque is require
As torque decreases, speed will increase and cemf w
increase. Since E_{eff} is equal to E_{app} minus the ce
the E_{eff} will decrease because of the increase in c
This decrease in E_{eff} causes armature current (I_a)
decrease and, since I_a also flows through the serie
field coils, field strength (β) will decrease.

If the load on a series motor is increased, torque
must _____, which will cause the speed an
cemf to _____. E_{eff} will _____,
causing an increase in both ____ and ____.

ease
ease

ease
β

32. Complete the chart below to show
a change in the load on a series
will affect T, E_{eff}, cemf, I_a, an
speed. Draw arrows in the approp
boxes, up (↑) to indicate increase and down (↓)
indicate decrease.

E_{app}	LOAD	SPEED	cemf	E_{eff}	I_a	β	
CONSTANT	INCREASE					↑	
CONSTANT	DECREASE					↓	

Your completed chart in frame 32 should look like
chart shown below. If your chart does not agree w
the chart below, return to frame 24 and redo the p
gram from that point.

E_{app}	LOAD	SPEED	cemf	E_{eff}	I_a	β	T
ONSTANT	INCREASE	↓	↓	↑	↑	↑	↑
ONSTANT	DECREASE	↑	↑	↓	↓	↓	↓

The primary use of the series motor in aviation is
starters for aircraft engines. The series motor i
used because it is able to supply the high torque
necessary for engine starting.

Many actuators for such devices as bomb-bay doors,
cockpit canopies, and wing flaps also use a series
motor. The series motor is used because these dev
must start under full mechanical load. The motor
erally used is the SPLIT-FIELD, D.C. SERIES motor,
which is easily reversed.

The motor generally used in aircraft actuators for
such things as cockpit canopies, bomb-bay doors, a
wing flaps is the _____ - _____
D. C. series motor.

35. The feature that makes the split-field series motor easily reversible is two separate sets of oppositely wound field coils.

Current flow through one coil will cause rotation in one direction, and when the current is switched to the other coil, the direction of rotation will reverse.

The split-field series motor is easily _____ because it is constructed with two sets of oppositely wound _____ _____.

36. The split-field series motor is used in many aircraft electrical actuators because of its high starting torque and its ability to be easily reversed.

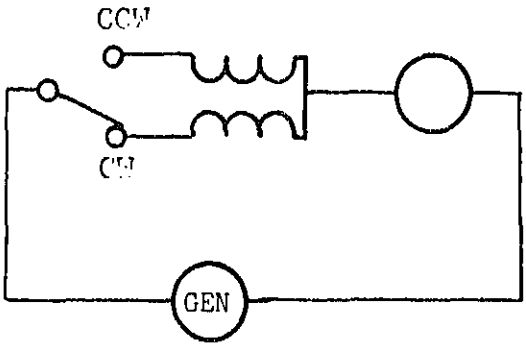
Because of the high starting torque and the ability to be easily reversed, electric actuators may be constructed with the _____-_____ series motor.

t-field

37. The motor generally used in D. C. actuators is the _____ - _____ series motor.

t-field

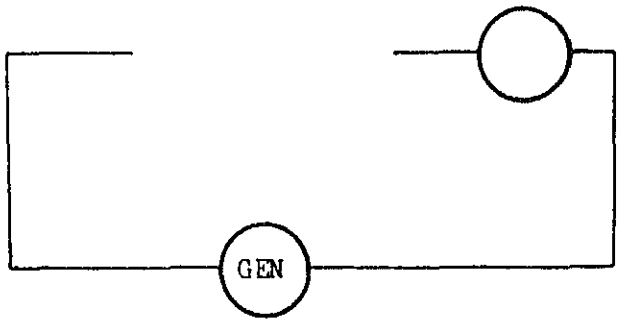
38. The schematic diagram below shows proper connection of a split-field series motor.



Notice, in the schematic diagram a that, if the switch is moved from position to the other, polarity of flux field produced will reverse. This will cause the direction of armature rotation to reverse.

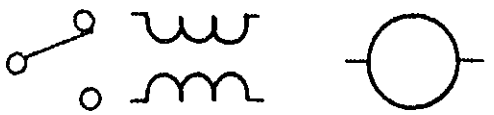
The two separate, oppositely wound field coils give the split-field motor the feature of being easily _____.

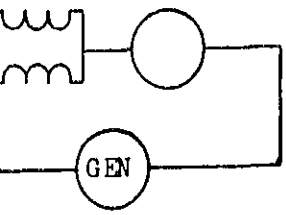
39. Draw the necessary symbols to complete the schematic diagram below to show the correct connection of a split-field series motor circuit.



The major difference between the standard series motor and the split-field series motor is the two oppositely wound _____ _____.

40. Draw the necessary connections between the symbols below that will complete a schematic diagram of a split-field series motor circuit.

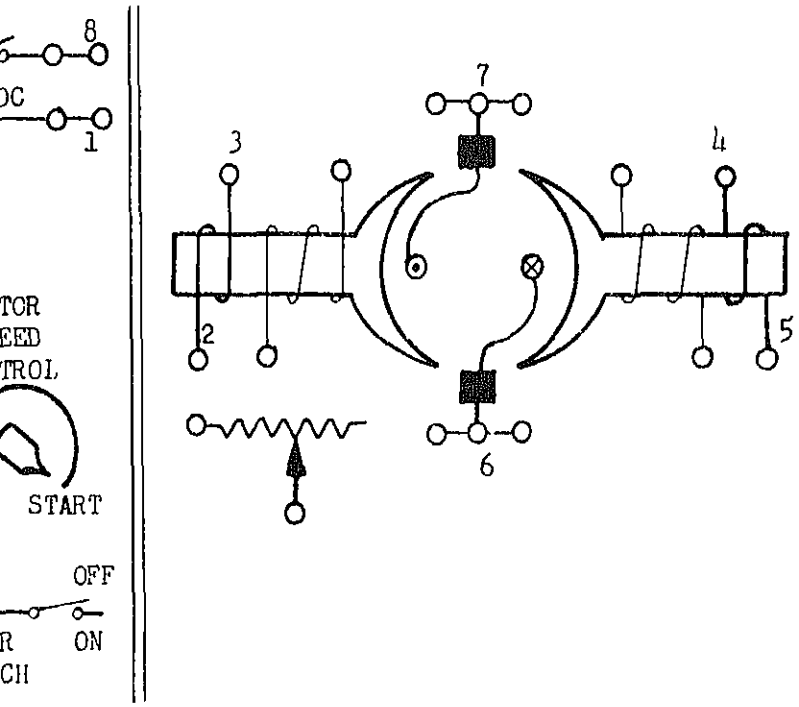




Your drawing in frame 40 should loo like the one shown to the left.

NOTE: The switch may be shown in either position.

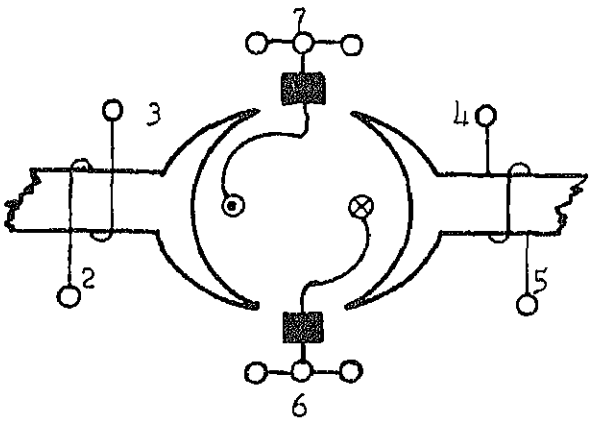
To aid you in understanding the operating characteristics of a series motor, a lab machine may be used to perform experiments. The diagram below shows a complete lab machine prior to making any connections For ease of explanation, the jacks that will be used for series motor experiments have been numbered.



The coils used for series motor experiments will be those containing the fewest turns, because a series motor field coil is made up of a _____ turn of _____ wire.

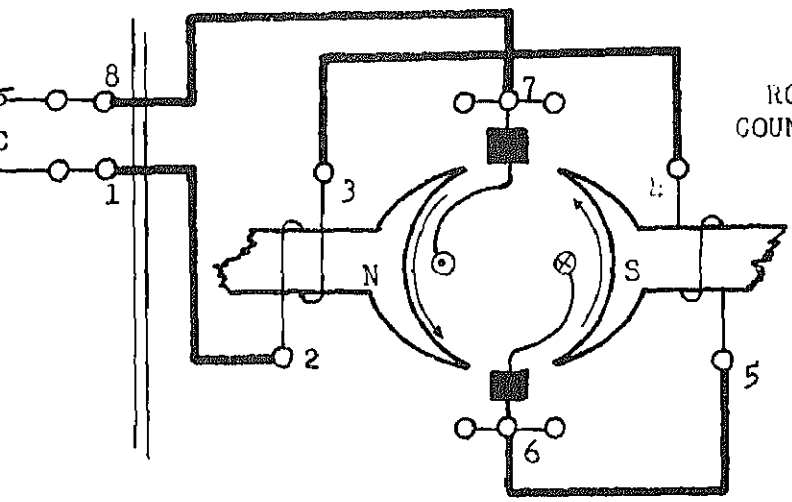
42. To make a clearer diagram, all parts unused in series motor experiments have been left off the diagram shown

low all instructions carefully and use the
" to check the polarity of the connections and
on of rotation. Draw in lines to indicate the
connections. NOTE: Instructions are given below the drawing.



jumper wire from the negative side of the 28-
ut (jack No. 1) to the lower left field coil
o. 2) so the face of the left pole piece has
polarity.
jumper wire from the upper left field coil
o. 3) to the right field coil (jack No. 4) so the
the right pole piece has a south polarity.
jumper from the right field coil (jack No. 5) to
ative brush (jack No. 6) so as to give the motor
clockwise rotation.
jumper from the positive brush (jack No. 7) to
itive side of the 28-VDC input (jack No. 8).

The connections you have just drawn on the diagram
frame 42 should match the connections shown on the
diagram below.



NOTE
ROTATION IS
COUNTERCLOCKWIS

Let's review a few points you have learned about th
series motor.

a. The series motor is widely used because it has
rapid acceleration and high starting _____

b. The series motor must always be connected to a
so that it will not build up excessive _____
and destroy itself.

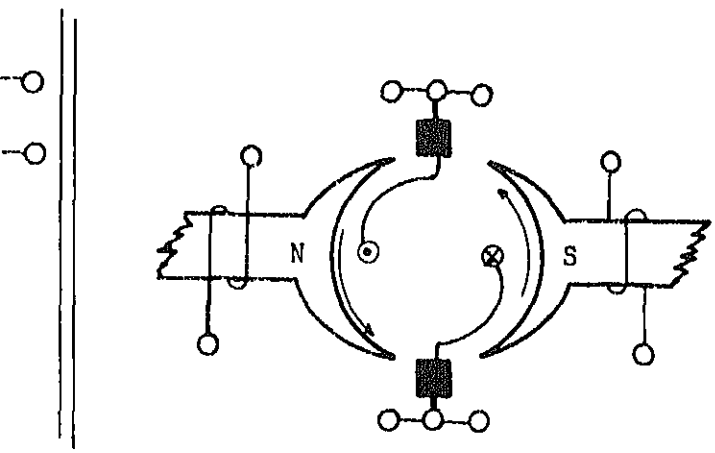
c. Torque in a series motor is proportional to the
square of the _____ current.

d. If the armature current in a series motor is do
the torque will increase to _____ time
the original amount developed.

ue c. armature Answers for frame 43

d d. four

lete the diagram below to show a lab machine ected to perform series motor experiments. Draw he connections between the jacks necessary to lete the diagram and set up the magnetic polarities n.



to frame 43 to check the accuracy of your ing.

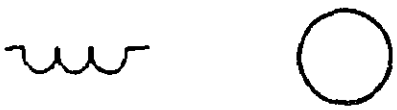
HAVE COMPLETED THE INSTRUCTIONAL PORTION OF PROGRAM; A SELF-TEST BEGINS ON THE NEXT PAGE.

SELF-TEST

for

THE SERIES MOTOR

Draw the necessary connections between the symbols below that will complete a schematic diagram of a series motor circuit.



Select, from the list of statements below, the reas
that series motors are widely used. Circle the lett
in front of the answer of your choice.

. Series motors have excellent speed control and a
not subject to overheating.

. Series motors are constant-speed motors and have
high starting cemf.

. Series motors have high starting torque and
rapid acceleration.

The armature current flowing through a series mot
that has a constant voltage applied is limited by
amount of _____ induced into the armature

Select, from the list of statements below, the
reason that a series motor must always be connecte
to a load. Circle the letter in front of the answ
of your choice.

a. The series motor must always be connected to a
load so that when it is started, it will not
build up excessive counterelectromotive force.

b. The series motor must always be connected to a
load so that when it is started, it will not
build up excessive speed and destroy itself.

c. The series motor must always be connected to a
load so that when it is started, it will not
build up excessive armature current.

Select, from the list of statements below, the relationship between torque and armature current in a series motor and the effect on torque when the armature current is doubled. Circle the letter in front of the answer of your choice.

a. Torque in a series motor is proportional to the square of the armature current; thus, doublin the armature current would cause an increase of four times the amount of torque being developed.

b. Torque in a series motor is proportional to the square of the applied voltage; thus, doubling the armature current would have no effect on the amount of torque being developed.

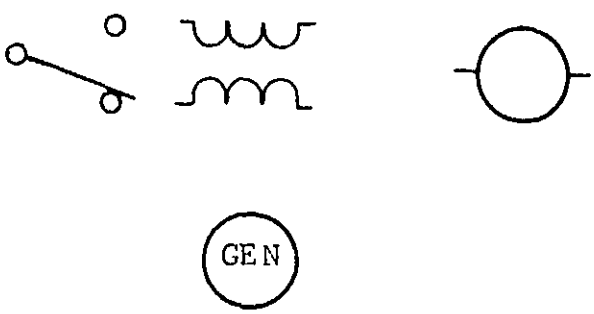
e. Torque in a series motor is proportional to the armature current divided by the applied voltage; thus, doubling the armature current would double the amount of torque being develope

plete the chart below to show how a change in the
d will affect torque, cemf, and I_a of a series
or. In the appropriate boxes, draw an arrow up
) to indicate increase or down (↓) to indicate
rease.

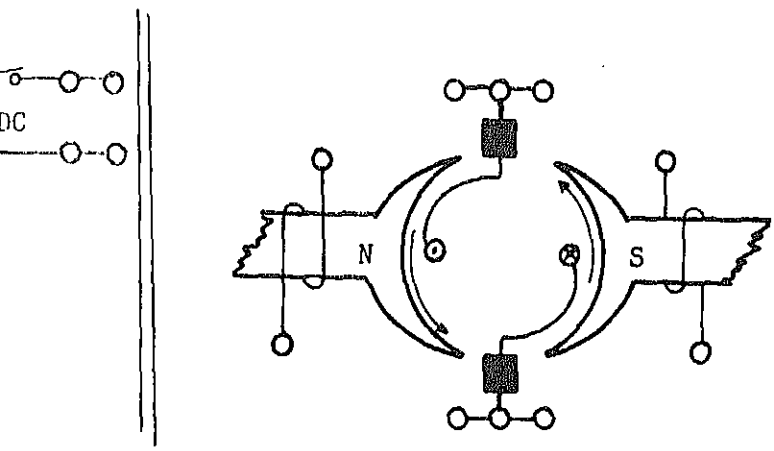
	LOAD	SPEED	cemf	E_{eff}	I_a	β	T
ANT	INCREASE	↓		↑		↑	
ANT	DECREASE	↑		↓		↓	

motor generally used in D.C. actuators is the
_____ - _____ series motor.

w the necessary connections between the symbols
ow that will complete a schematic diagram of a
it-field series motor circuit.



Complete the diagram below to show a lab machine connected to perform series motor experiments. Draw the connections between the jacks necessary to comple the diagram and set up the magnetic polarities shown.



END OF TEST.